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PENN - A MICRO COMPUTER PROGRAM FOR RECYCLED HOT MIX DESIGN AND A PRELIMINARY EVALUATION OF ITS FUNCTIONAL ADEQUACY

MATERIALS INFORMATION

ENGINEERING MATERIALS

PEN4 - A MICRO COMPUTER PROGRAM FOR RECYCLED HOT MIX DESIGN AND A PRELIMINARY EVALUATION OF ITS FUNCTIONAL ADEQUACY

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EXECUTIVE SUMMARY

In 1985, the Ontario Ministry of Transportation published an information report which contains a formula for predicting the penetration of the Abson recovered asphalt cement (A.C.) in a recycled hot mix (RHM).

This formula was subsequently programmed on the Ministry main frame computer for use by the regional pavement designers. The computer program is called PEN4.

Upon the request of the regional staff, a PEN4 micro computer program was developed in early 1988. This computer program is a modification of the PEN4 mainframe computer program with emphasis on improving accessibility, availability, usefullness and user friendliness.

The PEN4 micro computer program is fully menu driven and contains four functional applications. This computer program allows the pavement designers to examine various combinations of A.C. penetration grade, recovered A.C. penetration and percent reclaimed asphalt pavement (RAP) in a RHM so that an optimum pavement design can be selected.

A telephone survey on the functional adequacy of the PEN4 micro computer program, conducted in January 1989, revealed that the computer program is adequate and that it is widely used by pavement designers with exception of Northern region where a micro computer is not available in the section.

It is concluded that the PEN4 micro computer program has met the objectives for which it was developed.

1.0 INTRODUCTION

An information report titled MI-89 "Recycled Hot Mix - An Evaluation of Five Years Trend on Material Properties" (1) was published by the Ontario Ministry of Transportation in 1985. This report contains a formula which predicts the penetration of the Abson recovered asphalt cement (A.C.) in a recycled hot mix (RHM).

The formula was programmed on the Ministry main frame computer, and the computer program is called PEN4. The functional operation and computer application of the formula were subsequently published in a paper "Computer Modelling in the Design Stage of Recycled Hot Mix Projects" (2).

A survey on the performance of the PEN4 main frame computer program was conducted in 1987. The recommendations from the regional staff were that PEN4 should be modified to improve the accessibility, availability, usefulness and user friendliness.

On the basis of the regional recommendations, a modified micro computer base PEN4 computer program was produced and put in operation in 1988.

2.0 OBJECTIVES/DESIGN CRITERIA

Based on the discussion with the regional staff, the following objectives/design criteria were developed for the modification of the Pen4 main frame computer program:

(1) Produce a micro computer base PEN4 computer program because of the accessibility of micro computers,

-rewriting the computer program in GWBASIC computer language.

(2) Improve the availability,

- making the computer program available on computer diskette.

(3) Improve the usefulness to include four applications,

- (a) predicting the recovered A.C. penetration in a RHM for standard grade A.C. which includes 85/100, 150/200, 300/400, and 500Plus penetration grades.

- (b) predicting the recovered A.C. penetration in a RHM for a non-standard grade A.C.

- (c) calculating the virgin A.C. grade required in a RHM.

- (d) calculating the proportion of reclaimed asphalt pavement (RAP) in a RHM.

(4) Simplify the input and output procedures,

- reducing the number of steps.

(5) Improve the user friendliness,

- incorperating option menu and system prompting.

3.0 PROGRAMMING DETAILS

The PEN4 micro computer program is written in GWBASIC computer language, and it can be executed with an IBM compatible personal computer.

This computer program uses the following parameters in the calculations:

X = percent recovered A.C. in RAP.
X1 = (% RAP / 100) * (X / 100)
XX = (X1 / (1+ (Z / 100 - X1) / (1-Z / 100))) * 100 = percent of recovered A.C. from RAP in a RHM.
Z = percent A.C. in RHM.
Y = Z-XX = percent virgin A.C. added to RHM.
PO = penetration of recovered A.C. from RAP.
PN = penetration of virgin A.C.
PP = penetration of recovered A.C. from RHM.
PD = desired penetration of RHM in pavement.
CAO = 0.72 = aging factor of old asphalt.
CAN = aging factor of virgin asphalt.

To calculate the predicted A.C. penetration in a RHM for standard grade A.C., this computer program uses the following virgin A.C. penetration values in the calculation. These values are selected because experience has shown that approximately 80% of the A.C. supplied to Ministry contracts was at the low end of the standard A.C. grade range:

85 for 85/100 A.C.
150 for 150/200 A.C.
300 for 300/400 A.C.
560 for 500PLUS A.C.

If the actual A.C. penetration is known, use application no. 2 to calculate the recovered A.C. penetration in a RHM.

The following section outlines the formula used in each of the applications in this computer program:

1) To predict A.C. penetration in a RHM for standard grade A.C.

KNOWN VALUES: X, Z, PO, PN, CAN, CAO
UNKNOWN: PP

$$\log PP = 1/Z\ [XX \log(CAO*PO) + Y \log(CAN*PN)] \quad (1)$$

2) To predict A.C. penetration in a RHM for non-standard grade A.C.

KNOWN VALUES: X, Z, PO, PN, CAN, CAO.
UNKNOWN: PP

$$\log PP = 1/Z\ [XX \log(CAO*PO) + Y \log(CAN*PN)] \quad (1)$$

3) To calculate the virgin A.C. grade requires in a RHM.

KNOWN VALUES: X, Z, PO, PD, CAN, CAO.
UNKNOWN: PN

$$\log PN = \{[Z \log PD - XX \log(CAO*PO)] / [Z-X]\} - \log CAN \quad (1)$$

4) To calculate the proportion of RAP in a RHM.

KNOWN VALUES: A, Z, PO, PD, PN, CAN, CAO.
UNKNOWN: % RAP

$$\%\ RAP = \{Z\ [\log PD - \log(CAN*PN)]*100\} / \{\ X\ [\log(CAO*PO) - \log(CAN*PN)]\} \quad (1)$$

Note: To use this application select an estimated % RAP in the RHM so that a value of CAN can be estimated. If the result of % RAP is not within 5% of the estimated %RAP, use another estimated % RAP in the calculation and run the application again.

4.0 LOG ON/INPUT PROCEDURES

The following are the steps to use the PEN4 micro computer program. An example of the input procedures is contained in the appendix:

1) Set up the printer for printing.

2) Insert the PEN4 program disk in A drive of the micro computer.

3) Access to DOS SYSTEM in the micro computer.

4) Type "a:pen4".

5) Key ENTER to run the PEN4 program.

6) Follow the menu - enter the data and select application.

7) The program will be terminated when the users have elected not to do more calculations i.e. enter "N" at the system prompt.

5.0 OUTPUT PROCEDURES

The PEN4 micro computer program allows the users to either view or print the results by simply responding to system prompts. An example of a hard copy output is included in the appendix.

6.0 EVALUATION OF THE COMPUTER PROGRAM AFTER SIX MONTHS IN OPERATION

Six months after the PEN4 micro computer program was put in operation, a telephone survey was conducted on January 11, 1989 to evaluate the functional adequacy of the computer program.

The telephone survey asked the Heads of the Regional Geotechnical Sections the following questions, and the answers are based on a rating from 1 to 5, where 1 represents indequate and 5 represents most adequate:

Questions	Answers from each Region				
	C	E	SW	N	NW
1. How accessible is this computer program when you compare it to the main frame computer version of PEN4?	5	5	4	3	5
2. Is the computer program easy to use?	4	4	4	5	5
3. Is it user friendly? i.e. menu driven, system prompt.	4	5	4	4	4
4. Are the applications available in the computer program adequate for your operation?	4	5	4	5	5
5. Are the pavement designers more inclined to use PEN4 since it became available in micro computer?	4	3	4	2	5
6. Are the pavement designers using PEN4 more frequently since it became available in micro computer?	5	5	4	3	4
7. What is the percent split between the use of micro computer PEN4 and main frame computer PEN4? (micro / main frame)	100/0	100/0	100/0	33/67	100/0

Remark: Northern Region Geotechnical Section does not have a micro computer in the section at the present time. However, it is anticipated that once a micro computer installation becomes available the section will use the PEN4 micro computer program exclusively.

7.0 CONCLUSION

On the basis of the telephone survey, it is concluded that the micro computer base PEN4 computer program has met the objectives for which it was developed.

REFERENCES

1. TAM, K. K., 'Recycled Hot Mix - An Evaluation of Five Years Trend on Material Properties', MTO Report MI-89, February 1986.

2. McLuckie, R., Bruneau, R., Korgemagi, P., and Lynch, D.F. 'Computer Modelling in the Design Stage of Recycled Hot Mix Projects', Ministry of Transportation, Ontario. Presented at the 30th Annual Conference of the Canadian Technical Asphalt Association, Moncton, N.B., November 1985.

APPENDIX A - INPUT EXAMPLE

```
C:\>a:pen4

Enter Cont. No. or W.P. No. ? 88-97
Enter the recovered A.C. penetration in RAP   45
Enter percent A.C. in RAP   4
Enter percent A.C. in RHM as per design   5


Select one of the following applications:

   1. Enter 1 to calculate the predicted A.C. penetration in RHM
      which uses standard grade A.C.
   2. Enter 2 to calculate the predicted A.C. penetration in RHM
      which uses non-standard grade A.C.
   3. Enter 3 to calculate the grade of virgin A.C.
   4. Enter 4 to calculate the proportion of RAP

Enter 1, 2, 3  or 4   1

Enter initial percent RAP in RHM   25
Enter increment of percent RAP   5
Enter maximum percent RAP in RHM   45

**********************************************************************

(              W.P. No./Cont. No. 88-97

The following parameters were used in the calculations:
    A.C. PEN. in RAP =  45
    % A.C. in RAP =  4
    Total A.C. in RHM =  5

        The predicted penetration in RHM.

                    Grade of A.C.
% RAP     85/100    150/200   300/400   500PLUS
           (85)      (150)     (300)     (560)
 25          43        68       119       196
 30          43        66       112       179
 35          42        64       105       164
 40          41        60        97       148
 45          40        58        91       135

Note: Refer to appendix C in the user guide for the
      'TARGET' recovered penetration of R.H.M.

Do you wish to print the results. Enter Yes or No (Y/N) Y
```

Do you wish to do more calculations with this contract or
wo: project, enter YES or NO (Y/N)[y]

Do you wish to change the parameters in this contract/
work project, enter YES or NO (Y/N)[n]

Select one of the following applications:

1. Enter 1 to calculate the predicted A.C. penetration in RHM which uses standard grade A.C.
2. Enter 2 to calculate the predicted A.C. penetration in RHM which uses non-standard grade A.C.
3. Enter 3 to calculate the grade of virgin A.C.
4. Enter 4 to calculate the proportion of RAP

Enter 1, 2, 3 or 4 [2]

Enter initial percent RAP in RHM [25]
Enter increase in percent RAP [5]
Enter maximum percent RAP in RHM [30]
Enter virgin A.C. grade [150]

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PEN4 COMPUTER PROGRAM

W.P. No./Cont. No. 88-97

The following parameters were used in the calculations:
A.C. PEN. in RAP = 45
% A.C. in RAP = 4
Total A.C. in RHM = 5

Predicted A.C. penetration in RHM for virgin A.C. grade of
150

% RAP	Predicted Penetration in RAP
25	68
30	66

ote: Refer to appendix C in the user guide for the 'TARGET' recovered penetration of R.H.M.

o y wish to print the results. Enter Yes or No (Y/N)[y]

Do you wish to do more calculations with this contract or work project, enter YES or NO (Y/N) [y]

Do you wish to change the parameters in this contract/ work project, enter YES or NO (Y/N) [y]

Enter the recovered A.C. penetration in RAP [40]
Enter percent A.C. in RAP [4.3]
Enter percent A.C. in RHM as per design [5.5]

Select one of the following applications:

1. Enter 1 to calculate the predicted A.C. penetration in RHM which uses standard grade A.C.
2. Enter 2 to calculate the predicted A.C. penetration in RHM which uses non-standard grade A.C.
3. Enter 3 to calculate the grade of virgin A.C.
4. Enter 4 to calculate the proportion of RAP

Enter 1, 2, 3 or 4 [3]

Enter desired A.C. penetration of RHM in pavement [60]
Enter the percent RAP in RHM [25]

****

PEN4 COMPUTER PROGRAM

W.P. No./Cont. No. 88-97

The following parameters were used in the calculations:
A.C. PEN. in RAP = 40
% A.C. in RAP = 4.3
Total A.C. in RHM = 5.5
The desired A.C. PEN in RHM = 60
% RAP = 25

The required virgin grade A.C. penetration in RHM is 130

Do you wish to print the results. Enter Yes or No (Y/N)

```
Do you wish to do more calculations with this contract or
w  t project, enter YES or NO (Y/N)y

Do you wish to change the parameters in this contract/
work project, enter YES or NO (Y/N)n


Select one of the following applications:

   1. Enter 1 to calculate the predicted A.C. penetration in RHM
      which uses standard grade A.C.
   2. Enter 2 to calculate the predicted A.C. penetration in RHM
      which uses non-standard grade A.C.
   3. Enter 3 to calculate the grade of virgin A.C.
   4. Enter 4 to calculate the proportion of RAP

Enter 1, 2, 3  or 4   4

Enter desired A.C. penetration of RHM in pavement 66
Enter the percent RAP in RHM 25
Enter the virgin A.C. penetratio  value 150


**  **********************************************************


              PEN4 COMPUTER PROGRAM


              W.P. No./Cont. No. 88-97


The following parameters were used in the calculations:
    A.C. PEN. in RAP =  40
    % A.C. in RAP =  4.3
    Total A.C. in RHM =  5.5
    Desired A.C. PEN in RHM =  66
    Virgin A.C. PEN =  150
    Initial % RAP =  25

The % RAP in RHM is  27

If the calculated % RAP is not within 5% of the initial % RAP ,
recalculate % RAP until it is within 5% of the % RAP entered in the
calculation
Do you wish to print the results. Enter Yes or No (Y/N)n

Do  ou wish to do more calculations with this contract or
wo   project, enter YES or NO (Y/N)n

Do  ou wish to work on another contract/work project
enter YES or NO (Y/N)n

C:\>
```

APPENDIX B - OUTPUT EXAMPLE

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PEN4 COMPUTER PROGRAM

W.P. No./Cont. No. 88-97

The following parameters were used in the calculations:
A.C. PEN. in RAP = 45
% A.C. in RAP = 4
Total A.C. in RHM = 5

The predicted penetration in RHM.

% RAP	Grade of A.C. 85/100 (85)	150/200 (150)	300/400 (300)	500PLUS (560)
25	43	68	119	196
30	43	66	112	179
35	42	64	105	164
40	41	60	97	148
45	40	58	91	135

Note: Refer to appendix C in the user guide for the 'TARGET' recovered penetration of R.H.M.

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PEN4 COMPUTER PROGRAM

W.P. No./Cont. No. 88-97

The following parameters were used in the calculations:
A.C. PEN in RAP = 45
% A.C. in RAP = 4
Total A.C. in RHM = 5

Predicted A.C. penetration in RHM for virgin A.C. grade of 150

% RAP	Predicted Penetration in RAP
25	68
30	66
35	64
40	60

Not Refer to appendix C in the user guide for
'TARGET' recovered penetration of R.H.M.

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PEN4 COMPUTER PROGRAM

W.P. No./Cont. No. 88-97

The following parameters were used in the calculations:
A.C. PEN in RAP = 40
% A.C. in RAP = 4.3
Total A.C. in RHM = 5.5
The desired A.C. PEN in RHM = 60
% RAP = 25

The required virgin grade A.C. penetration in RHM is 130

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PEN4 COMPUTER PROGRAM

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W.P. No./Cont. No. 88-97

The following parameters were used in the calculations:
A.C. PEN in RAP = 40
% A.C. in RAP = 4.3
Total A.C. in RHM = 5.5
Desired A.C. PEN in RHM = 60
Virgin A.C. PEN = 150
Initial % RAP = 25

The % RAP in RHM is 39

If the calculated % RAP is not within 5% of the initial % RAP, recalculate % RAP until it is within 5% of the % RAP entered in the calculation